

Energy Storage

Platform Technologies for
Changing the Game

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Transportation

Energy Density
Cost
Cycle life
Stability



Power Grid

Cost
Capacity (power)
Duration
Reliability



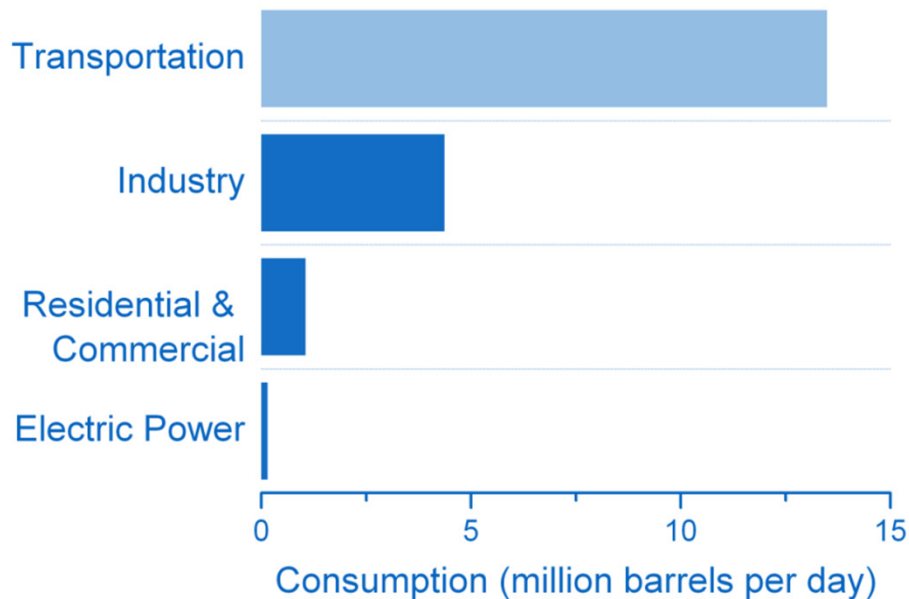
Control Systems

Sense
Model
Control

Transportation

Increase Adoption of Electric Vehicles

2010 U.S. Petroleum Demand



TESLA MOTORS



Tesla Model S

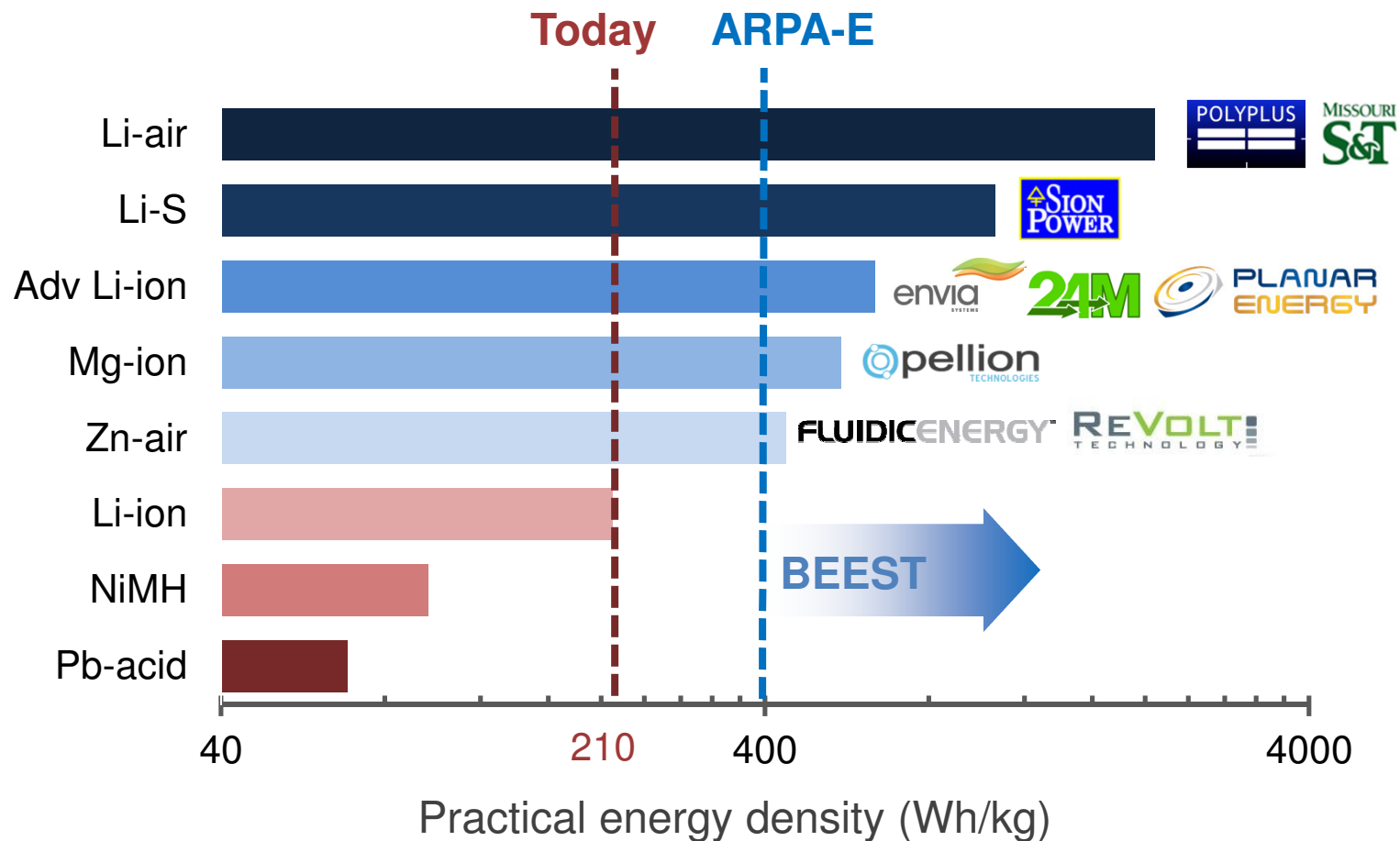
Metric	Units	85 kWh
<u>Vehicle</u>		
Price	\$	70,000
Range	mi	300
<u>Battery</u>		
Total cost*	\$/pack	43,000
Cell/pack energy density*	Wh/kg	200/120
Cell/pack cost*	\$/kWh	300/500

* Estimated

Source: <http://www.teslamotors.com/models/options>

Challenge: Current batteries are too expensive and low energy density

Opportunity: New battery chemistries with 2-5x the energy density



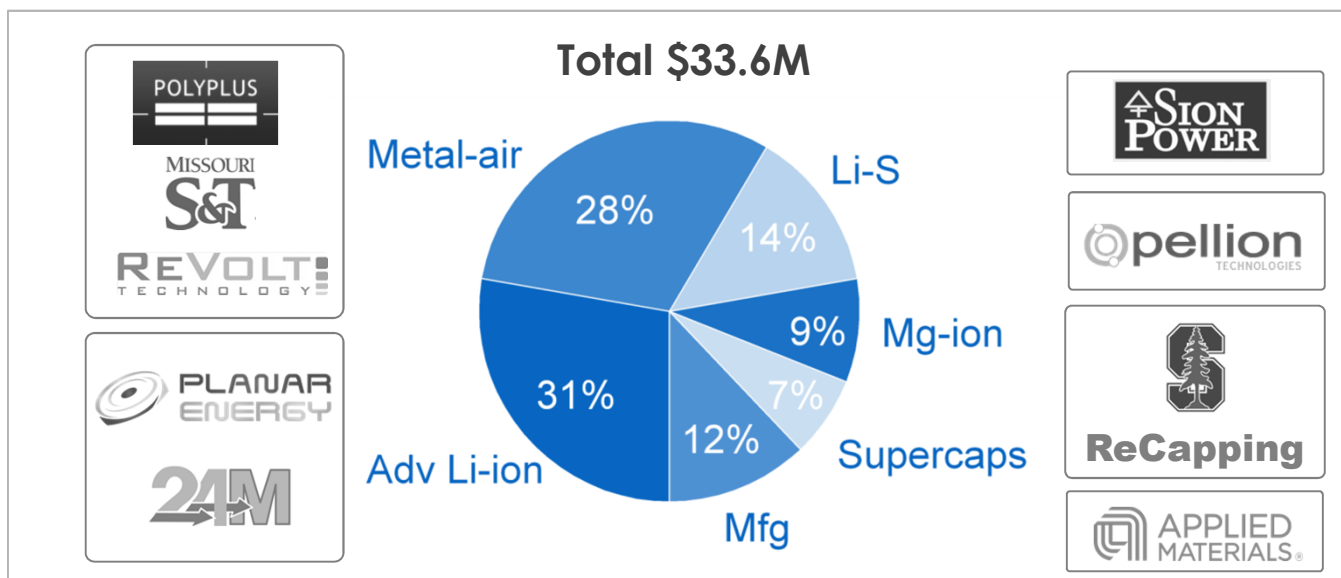
BEEST Program

Batteries for Electrical Energy Storage for Transportation

Objectives

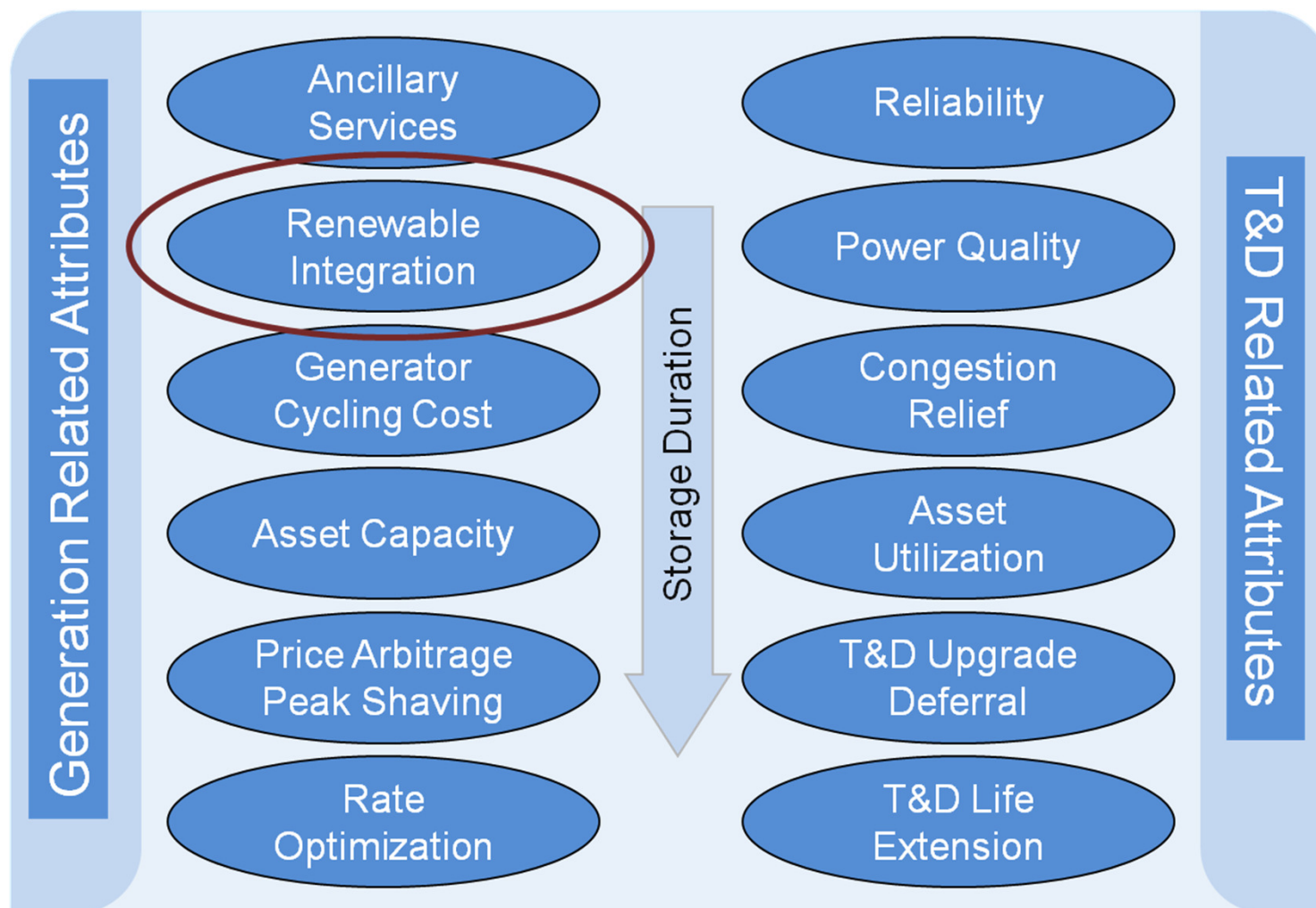
- Cost-competitive with traditional cars
- 30% of today's cost at 2-5x energy storage
- 300-500% longer battery life + range

2-5x performance
+
1/3 price



Power Grid

Electric Grid Energy Storage

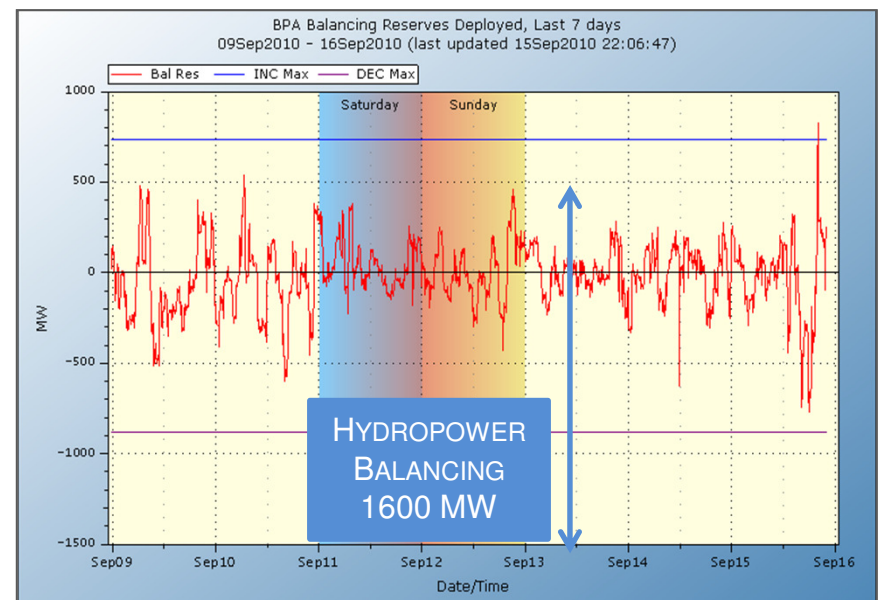
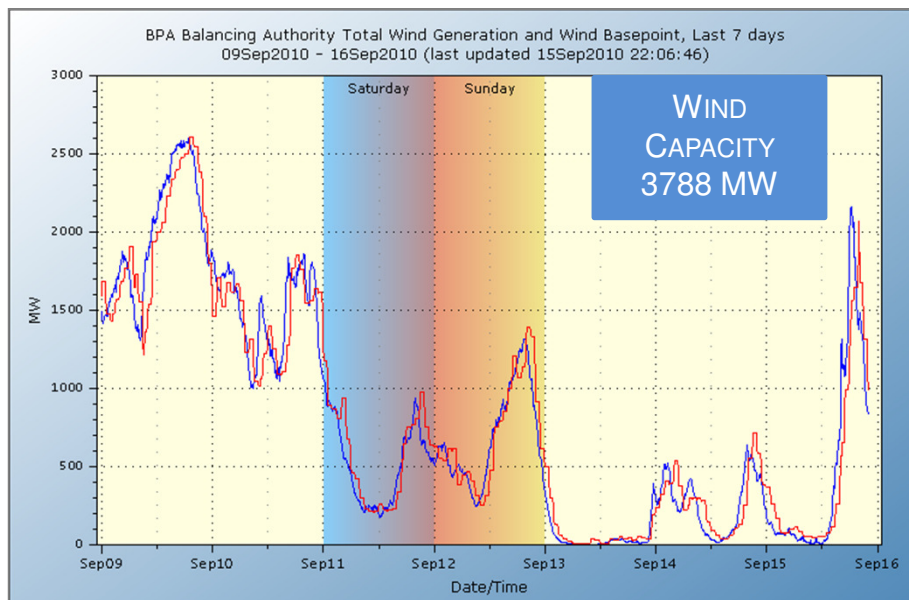


GRIDS Program

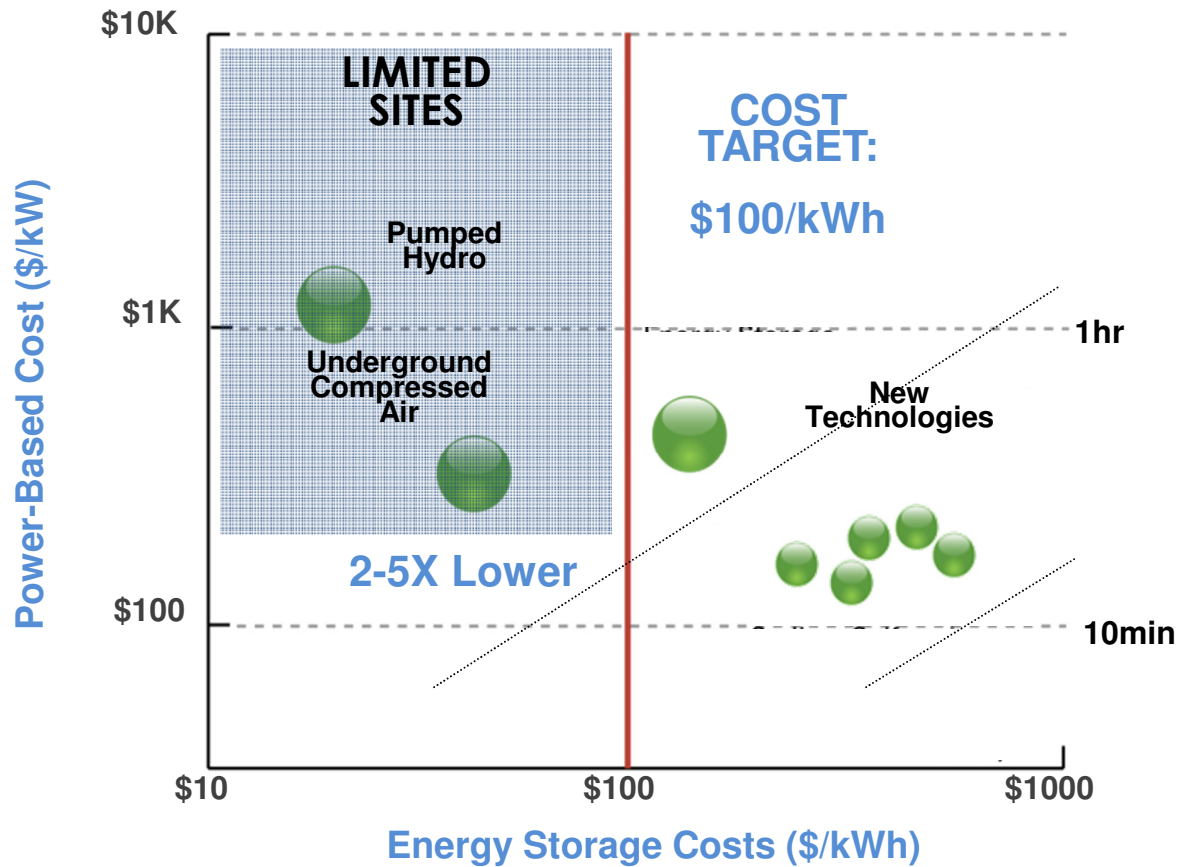
Grid-scale Rampable Intermittent Dispatchable Storage

Challenge:

Balance & Firm Renewable Generation at High Penetration (>20%) on the Power Grid



GRIDS Technologies



Minimum Response Time



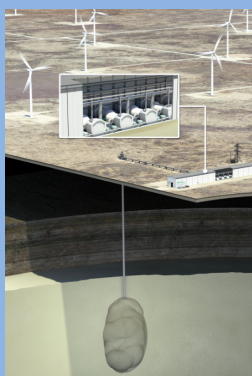
Seconds



Minutes

GRIDS Projects

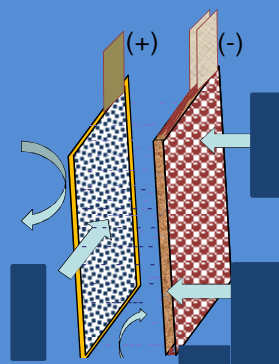
General Compression



Isothermal Compression:
technology bridge to
commercial follow-on



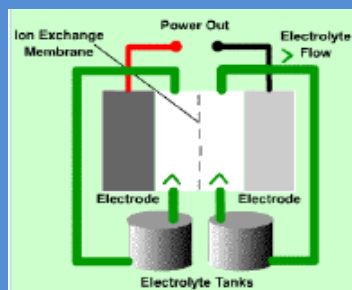
University of Southern California



Iron-Air Battery:
iron is cheap, air is free



United Technologies



Ultra-high Power
Density Flow Battery



City University of New York



Cheap Recyclable
Alkaline Battery



Robust Control of Energy Storage

State-of-the-art

- Sensing limited to very few measurements (I, V, T)
- Non-representative generic ECM & rule-based control algorithms
- Inaccurate estimation of SOH
- Lack of reliable safety and lifetime indicators



As high as 100% excess capacity



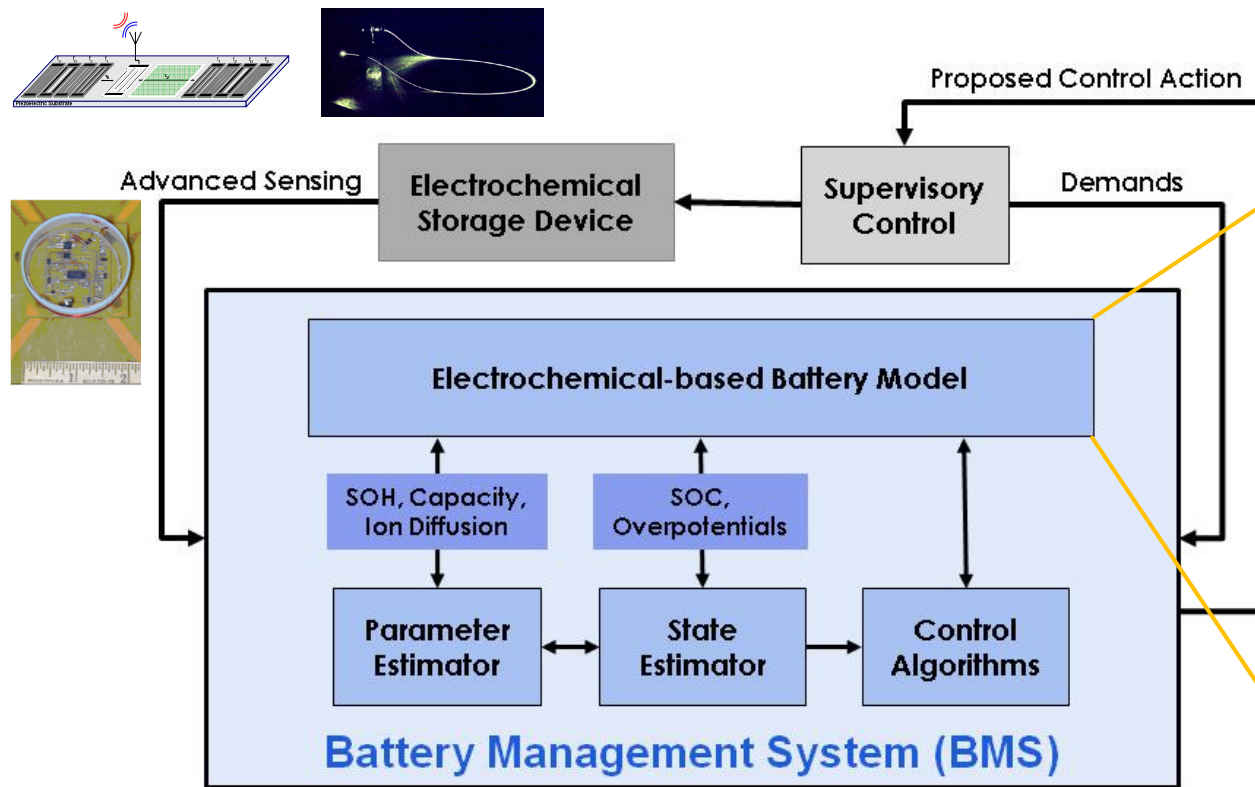
U.S. military battery "graveyard" in Iraq



- Restricted utilization & Reduced Lifetime
- Prohibits secondary market use
- Use of sub-optimal technologies

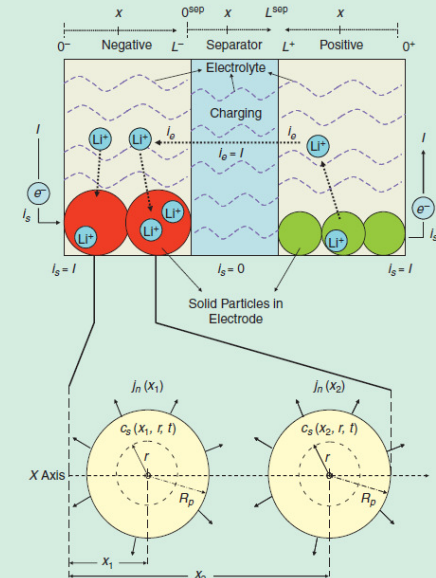
Advanced Energy Management Systems

Maximize performance of energy storage by Sensing, Modeling, & Control



Battery Model

Chaturvedi, et al., June 2010



RFI on Robust Control of Energy Storage - issued February 17, 2012

What makes an ARPA-E project?

1. Impact

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

2. Transform

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

3. Bridge

- Between basic science and applied technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

4. Team

- Best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

Thank you